MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2016/2017

ENT2016 – SOLID STATE ELECTRONICS
(Nano)

01 MARCH 2017
09.00 – 11.00
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 6 pages with 4 Questions only.
2. Attempt all **FOUR** questions. The distribution of the marks for each question is given.
3. Please print all your answers in the Answer Booklet provided.

Question 1

(a) In solid atoms can have **THREE** (3) different types of arrangement. With relevant diagram illustrate and compare the **THREE** types of atomic arrangement.

[6 marks]

(b) In crystallography what is 'Bravais lattice'?

[2 marks]

(c) For the intercepts x, y, and, z with values of 3, 1, and 2 respectively, find the Miller Indices.

[3 marks]

(d) Consider at room temperature Lithium (Li) has Body Centered Cubic (BCC) crystal structure. If Li has a density of 8.57 g cm^{-3}, and an atomic mass of 92.90638g mol^{-1}.

(i) Determine the lattice parameter *a* of Li. [2 marks]

(ii) Calculate the atomic concentration of Li. [2 marks]

(iii) Find the atomic radius of Li. [2 marks]

(iv) Analyze the planar concentrations as the number of atoms per nm^2 of the (100), (110) and (111) planes of Li.

[6 marks]

(e) In a polysilicon crystal structure, why impurities are easily introducing along the grain boundaries?

[3 marks]

Continued...

Question 2

(a) With the aid of suitable diagrams, briefly describe the following:

(i) Consequence of Vacancy defect in crystal structure [3 marks]

(ii) Schottky and Frenkel defects. [5 marks]

(b) With the aid of a diagram, illustrate different types of bond associated with a crystal surface.

[2 marks]

(c) The potential energy, E, per Na^{+}–Cl^{-} pair within the NaCl crystal depends on the interionic separation, r, in the same fashion as in the NaCl crystal,

$$E(r) = -\frac{e^2 M}{4\pi\varepsilon_o r} + \frac{B}{r^m}$$

where for NaCl, $M = 1.748$, $B = 6.972 \times 10^{-96}$ J m^8 and $m = 8$.

(i) Find the equilibrium separation (r_o) of the ions in the crystal.

[7 marks]

(ii) Given the ionization energy of Na is 5.14 eV and the electron affinity of Cl is 3.61 eV, ionic cohesive energy is 7.84 eV, calculate the atomic cohesive energy of the NaCl crystal as joules per mole.

[4 marks]

(d) What is the de Broglie wavelength of an electron travelling at 7 x 10^6 m.s^{-1}? What is the relation between the de Broglie wavelength and the average spacing of atoms?

[4 marks]

Continued...

Question 3

(a) Briefly Explain:

i. Black body radiation [2 marks]

ii. Ultraviolet catastrophe [2 marks]

iii. Wave-particle duality [2 marks]

(b) Thomas Young performed his famous double slit experiment which seemed to prove light as a wave. Briefly explain wave like properties of light based on 'Young's Double-Slit experiments' and explain how constructive and destructive interference can occur. [5 marks]

(c) Show that if the uncertainty in the position of a particle is on the order of its de Broglie wavelength, then the uncertainty in its momentum is about the same as the momentum value itself.

[5 marks]

(d) Consider a vacuum tube device as illustrated in Figure 3 (d). Cesium metal is to be used as the photocathode material in a photoemissive electron tube because electrons are relatively easily removed from a cesium surface. The work function of a clean cesium surface is 1.9 eV.

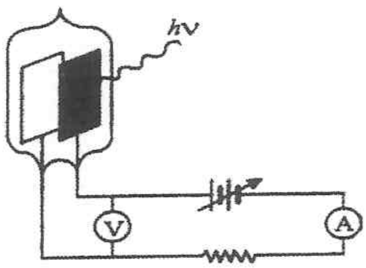

Figure 3 (d): Vacuum tube device consists of Cesium metal as photocathode.

(i) What is the longest wavelength of radiation which can result in photoemission? [3 marks]

(ii) If blue radiation of wavelength 450 nm is incident onto the Cs photocathode, what will be the kinetic energy of the photoemitted electrons in eV? [4 marks]

(iii) What should be the voltage required on the opposite electrode to extinguish the external photocurrent? [2 marks]

Continued...

Question 4

(a) In 1900, Paul Drude provides a model to explain the transport properties of electrons in materials. What are the **SIX** (6) assumptions allied with Paul Drude's model.

[6 marks]

(b) Find the intrinsic carrier concentration in gallium arsenide GaAs at $T = 500\ K$.

[4 marks]

(c) A Si crystal has been doped with Phosphorous (P). The donor concentration is 10^{15} cm^{-3}. Find the conductivity and resistivity of the crystal.

[5 marks]

(d) A semiconductor bar of length 8 μm, cross sectional area of 2 μm^2 is uniformly doped with donors with a much higher concentration than the intrinsic concentration (10^{11} cm^{-3}) such that ionized impurity scattering causes its majority carrier mobility to be function of doping as:

$\mu = 800/\sqrt{[N_D/(10^{20}\ cm^{-3})]}\ cm^2/V\text{-}s$

If the electron drift current for an applied voltage of 160 V is 10 mA, calculate the doping concentration in the bar. If the minority carrier mobility is 500 cm^2/V-s, and its saturation velocity is 10^6cm/s for fields above 100 kV/cm calculate the hole drift current. What are the electron and hole diffusion currents in the middle of the bar?

[10 marks]

Continued...

Useful constants and materials properties:

Physical constants		
Boltzmann's constant	k	1.3807×10^{-23} JK^{-1} 8.617×10^{-5} eVK^{-1}
Planck's constant	h	6.626×10^{-34} J s
Thermal voltage @ 300 K	kT/e kT	0.0259 V 0.0259 eV
Electron mass in free space	m_e	9.10939×10^{-31} kg
Electron charge	e	1.60218×10^{-19} C
Effective density of states in the conduction band (for Si)	N_c	2.8×10^{19} cm^{-3}
Effective density of states in the Valence band (for Si)	N_v	1.04×10^{19} cm^{-3}
Permeability of free space	μ_o	$4\pi \times 10^{-7}$ H/m
Permittivity of free space	ε_o	8.85×10^{-12} F/m
Avogadro's number	N_A	6.023×10^{23} mol^{-1}

Semiconductor Materials Properties at 300 k					
Materials	*Energy gap*	*Intrinsic concentration*	*Electron mobility*	*Hole mobility*	*Dielectric Constant*
Notations	E_g (eV)	n_i (cm^{-3})	μ_e (cm^2 V^{-1} s^{-1})	μ_h (cm^2 V^{-1} s^{-1})	ε_r
Si	1.10	1×10^{10}	1350	450	11.7
GaAs	1.42	2.1×10^{6}	8500	400	13.1
Ge	0.66	2.3×10^{13}	3900	1900	16

End of Paper